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"Data projector"
(Dataprojektori)

Hakemus on hakemusdiaariin **16.06.2003** tehdyn merkinnän mukaan siirtynyt seuraaville henkilöille:
1. Alasaarela, Ilkka, Oulu
2. Alasaarela, Mikko, Oulu

The application has according to an entry made in the register of patent applications on **16.06.2003** been assigned to
1. Alasaarela, Ilkka, Oulu
2. Alasaarela, Mikko, Oulu

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Apulaistarkastaja

Maksu 50 €
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Maksu perustuu kauppa- ja teollisuusministeriön antamaan asetukseen 1027/2001 Patentti- ja rekisterihallituksen maksullisista suoritteista muutoksineen.

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Data projector

Field

The invention relates to devices for displaying images by projection.

Background

The current trend of mobility drives the consumer demand towards ever smaller portable devices, such as mobile phones, portable digital assistants, music and video players, laptop PCs, etc. As the size becomes smaller and the functionality higher, there is a fundamental problem of showing large enough visual images with very small devices. Because the size of a fixed screen cannot grow without increasing the size of the device itself, the only reasonable way to conveniently provide visual images from small devices is to project them using a data projector. However, the current data projectors are large in size and inefficient in nature.

The commercially available data projectors use high intensity broadband light sources, such as incandescent bulbs or arc lamps. These light sources have inherently low efficiency and produce heat, which consumes high amounts of energy and requires a cooling system. The use of LED as a light source of data projector has also been proposed. However, these solutions do not have good enough optical efficiency. In these systems, the light source has poor external efficiency, and in addition to that, a large part of the light is lost in collimation. Secondly, these solutions are still large in size and expensive with high power consumption, and they cannot be operated with widely used battery technologies.

Brief description of the invention

An object of the invention is to provide an improved data projector that is small, inexpensive and has small power consumption. According to an aspect of the invention, there is provided a data projector, the data projector comprising: a microdisplay having an image to be projected, at least one light source transmitting in a narrow band of the visible radiation, a beam forming component for each light source, each beam forming component comprising at least one diffractiv- element, and each beam forming element being designed to provide a desired projection shape and a uniform illumination onto the micro display, and a focusing optical unit for projecting the image of the micro display on a target.

Preferred embodiments of the invention are described in the dependent claims.

The method and system of the invention provide several advantages. The data projector has good power efficiency and the image of the projector has even brightness. The data projector can be made small in size, low in weight and durable.

List of drawings

In the following, the invention will be described in greater detail with reference to the preferred embodiments and the accompanying drawings, in which

Figure 1 shows the microdisplay illumination with conventional optical arrangement,

Figure 2 shows the microdisplay illumination with beam forming component,

Figure 3A illustrates a beam forming component integrated with a light source,

Figure 3B illustrates ray traces when a beam forming component is not used,

Figure 3C illustrates a beam forming component integrated with a light source,

Figure 4A presents a single color projector with a transmissive microdisplay,

Figure 4B presents a single color projector with a transmissive microdisplay,

Figure 4C presents a single color projector with reflective microdisplay,

Figures 5 shows an LCD-projector, in which both the polarization states are utilized,

Figures 6 shows an LCD-projector, in which both the polarization states are utilized,

Figure 7 shows a color projector with an X-cube beam combiner,

Figure 8 shows an embodiment of a color projector with an X-cube beam combiner,

Figure 9 shows a color projector with a chromatic mirror beam combiner,

Figure 10 shows a color projector with a chromatic mirror beam combiner,

Figure 11 shows a color projector with a chromatic mirror beam combiner,

Figure 12 shows a color projector with a lenticular lens,

Figure 13 shows a color projector with a lenticular lens,

Figure 14 shows a color projector with serial illumination,

Figure 15 shows a color projector with serial illumination and reflective microdisplay,

Figure 16 shows a color projector with a reflective microdisplay,

Figure 17 shows a color projector, in which both the polarization states are utilized, and

Figure 18 shows a color projector, in which both the polarization states are utilized.

Description of embodiments

The efficiency of the projector is degraded by the losses which include: spectral losses (if wideband sources are used), losses due to poor internal efficiency of the source, losses due to poor external efficiency of the source (for example with LEDs), light collection losses (collimation losses), integration losses (if several light beams are combined), color separation losses (losses in dichroic mirrors used to split the light into red, green and blue components), polarization losses (if LC-microdisplay is used), reflection or transmission losses at the microdisplay itself for example due to a poor fill factor (gaps between the pixels), color combination losses (for example when using X-cube or dichroic mirrors), and losses in the projection lens (reflection losses on the lens surfaces).

It is extremely important that the light loss can be minimized in every aspect. It is also desirable to be able to maximize the internal and external quantum efficiencies of the light source. The light should only be directed to the active area of the micro display which functions as a modulator. The loss in the optical components and in the micro display should be minimized.

Spectral losses occur when incandescent bulbs or arc lamps are used as a light source. They emit light with a very broad wavelength band and most of the electric power is converted to heat. By using LED (Light Emitting Diode) sources, for example, this problem can be avoided because is it possible to create light only for the needed wavelength bands (red, green and blue).

The total efficiency of LEDs depends on the internal quantum efficiency, and the external efficiency. The definition of internal quantum efficiency is the ratio of the number of electrons flowing in the external circuit to the number of photons produced within the device. The external quantum efficiency means the ratio of the number of photons emitted from the LED to the number of internally generated photons. The internal quantum efficiencies can be near 100%, for example 99%, with certain materials and structure designs. However, a large fraction of the generated light is never emitted from the semiconductor, but is trapped by total internal reflection. The external efficiency ratio can be as poor as $1/(4n^2) \approx 1/50$, (where $n = 3.5$ is the refractive index of the semiconductor) for the conventional LEDs. More sophisticated LED designs include features that allow a greater fraction of the internal light to escape. These features include hemispherical or conical semiconductor domes over the LED, surface roughening, transparent substrates and superstrates and photon recycling. Resonant-cavity LEDs use quantum electrodynamical enhancement of spontaneous emission in high-finesse resonators. These methods allow up to 30% external efficiencies, which is still far below the optimum case. Still another proposed method is to cut the semiconductor chip into a truncated inverted pyramid by which 55% external efficiencies have been achieved.

Light collection loss presents, along with the poor external efficiency, one of the most severe light losses in the projector system. Most of the light coming from an LED can be collimated by using a convex lens or a secondary optics based on conical total internal reflection. This forms a relatively compact beam which has circular symmetry. However, the circular beam is not ideal because the microdisplay can have a rectangular shape. Because of this shape difference a big portion of the light is lost. The solution using lenses for collimation may also suffer from vignetting, i.e. the intensity of light is not even across the microdisplay.

Integration losses, color separation losses and color combination losses are difficult to improve in practice. They can be minimized by choosing dichroic mirrors, X-cubes and beamsplitters carefully.

When using an LC-based microdisplay, the polarization losses are significant resulting in a loss of ov r 50 %. Typically nothing is done to avoid these losses.

The losses in the microdisplay are caused by the reflections, scattering or absorption at the microdisplay itself, for example, due to poor fill factor (gaps between the pixels). When using an LC-based microdisplay, the loss is typically between 20% - 40%. The losses due to a poor fill factor can be substantially decreased by applying so called micro-lens arrays (MLA) before and after the liquid crystal panel which focuses the collimated light to go through the pixels and collimates the light again after the panel. MLA reduces the gap loss significantly.

The losses in the projection lens can be minimized by using antireflection coated lenses. This is a question of costs, whether to stand this loss or to use the more expensive lenses.

Sources

A data projector may comprise one or more narrow band sources, which work in the visible range. The bandwidth of each narrow band source is narrow in comparison to the whole visible range (400 nm ... 750 nm), for example the bandwidth can vary from monochromatic light to more than a hundred nanometers (the band can be, for example, 100 nm, 50 nm, 20 nm or less). The data projector can be provided with one or more sources which all emit light with the same wavelength band. The sources can also provide light with different bands, i.e. colors. Typically the sources may together provide light with red, green and blue. The sources can be for example LEDs, OLEDs or quantum-well LEDs. The data projector of the present solution can provide a projection using three nearly monochromatic high efficiency LEDs, beam forming components, lenses or diffractive elements for collimation, a micro display and focusing lenses.

Beam forming component

The function of the beam forming component is to couple the light out from the source chip and provide the outcoupled beam with a desired shape and divergence angle. The beam forming component also provides uniform illumination to the microdisplay. Figure 1 shows an illuminating beam 106 on the microdisplay 104 when a light source 102, such as LED, is used with conventional optical arrangements (not shown in Figure 1). As it is seen, a substantial part of the light 106 does not hit the microdisplay 104. In addition, the illumination is not uniform and suffers from vign tting (shown using different hatchings).

Figure 2 in its part shows an illuminating beam 108 on the microdisplay 204 when the light source 202 is used with a beam forming component (not shown in Figure 2) of the present solution. The shape of the beam 208 is nearly rectangular so that it suitably fills the microdisplay 104. In addition to that, the microdisplay is illuminated uniformly so that vignetting is minimized.

Figure 3A shows the light source with a beam forming component. The beam forming component 320 comprises at least one diffractive element 308. Optionally it may also comprise a refractive component 310. These diffractive and refractive elements can be integrated together to form a single beam forming component. A source chip 302, for example an LED chip, is mounted on a reflecting metal layer 304. The metal layer 304 reflects the downwards emitted light. The other function of the metal layer is to conduct any heat away. The system is integrated with a transparent material 306 the refractive index of which is near that of the source chip 302. The upper surface of the transparent material has a certain shape and texture. Because the refractive indexes of the transparent material and the source chip are close together, there is no substantial light loss between them.

Figure 3B presents a structure otherwise similar to that of Figure 3A, except that the transparent material 306 has a shape of rectangular block with straight sides. This demonstrates the situation without the diffractive and refractive components. The object would be to obtain efficient light beam, which propagates upwards from the source chip. In Figure 3B only the light 312 which is emitted almost upwards from the chip can avoid total internal reflection, because of the refractive index difference between the block material and air. In addition to that, the small angle is diverged in the border of the transparent material and air. After all, the external efficiency of the source is very low and the outcoming beam is diverges noticeably.

The beam forming component 320 can maximize the external efficiency by designing the direction and the patterning of the outer surface of the transparent material so that the reflections are minimized. The diffraction element 308 has a diffractive surface pattern. The surface comprises local diffractive areas which have been optimized so that most of the light coming from the source chip to that area is diffracted into desired direction. For example by using suitable binary or blazed profile, it is possible to obtain, for example, 95 % of the light diffracted to the desired direction. The directionality is the better the smaller the source chip is in comparison to the distance from the surface point

to the source chip. The outcoming beam direction can be designed to be made predetermined by suitable design and by using a various diffractive patterns which vary over the surface. The period, the shape and pattern, the modulation depth and the duty cycle can be set to best fulfil the desired function. Typically just above the source chip the surface is only refractive, whereas elsewhere the surface is diffractive. If the beam forming component is well designed, it is possible to raise the external efficiency of an LED for example 90 %. Another advantage of the beam forming component is that it is substantially smaller than its purely refractive counterparts, which also have worse performance. The beam forming component can be easily mass-produced by well known mass production methods. The beam forming component can be integrated with the source so that they form a single unit.

In another embodiment of the beam forming component, which is shown in Figure 3C, the source chip 302 is sunk in a reflector cup. Figure 3C also shows that the transparent material can also be nearly rectangular in its shape, the surface of which comprise diffractive areas and optionally also refractive areas.

The needed geometrical shape of the refractive element can be calculated by using conventional optical design methods. For example, ray-tracing softwares may be used in simulations. Usually analytical functions are better for searching the suitable surface shape.

In principle, the needed geometrical parameters of the diffractive component can be solved analytically in a very simple case. However, the analytical solution is usually too complex in comparison to much faster and simpler numerical modeling. Numerical modeling of diffraction gratings is possible for example by using GSOLVER (Grating Solver Development Company, Allen, Texas, USA) software. GSOLVER utilizes a full 3-dimensional vector code using hybrid Rigorous Coupled Wave Analysis and Modal analysis for solving diffraction efficiencies of arbitrary grating structures for plane wave illumination. In addition to the commercial software, a skilled professional can use conventional programming tools for building more sophisticated modelling tools of his own.

The beam forming component must be designed taking into account the whole optical system of the device. Especially the beam forming component must be designed with the possible collimating unit, which collimates the diverging beam from the beam forming component.

One embodiment of the beam forming component comprises two or more beam forming components, which can comprise a single unit, so that light passes through all the components.

Source unit

A source 302 with a beam forming component 320 provides, or sources each with a beam forming component provide a source unit. The source unit provides a light beam which has desired shape, typically rectangular, and desired divergence angle.

One embodiment of the source unit comprises one narrow band source with a beam forming component, which can be integrated together. The beam forming component is designed to provide a desired beam shape and divergence angle.

Another embodiment of the source unit comprises several narrow band sources, each providing light with the same wavelength band, and each having a beam forming component of their own. The beam forming components are designed so that the beams together form the desired beam shape and divergence angle. The beam forming components and optionally also the sources can be integrated into a single unit, which may be beneficial in a certain device assembly.

Still another embodiment of the source unit comprises more than one narrow band sources, each of which are working with a different narrow wavelength band. Typically the source unit comprises red, green and blue LEDs, for example. Each source has a beam forming component which can be integrated into it. The beam forming components are designed so that beams with each wavelength band have the desired shape and divergence angle. The beam forming components and optionally also the sources can be integrated into a single unit for easier assembly. One possibility is also to have several light sources for each wavelength band. For example, the source unit may comprise 6 LEDs so that there is 2 LEDs with red, green and blue colors. In this case there are also 6 beam forming components, which may form a single beam forming structure.

Collimating unit

The collimating unit means an optical assembly which collimates the diverging light beam. The collimating unit can comprise for example a single lens, a Fresnel lens, a single mirror, a diffractive optical element, a hybrid re-

fractive-diffractive element, or a combination of the said components. Preferably the collimating unit comprises one Fresnel lens, one hybrid refractive-diffractive element or one convex lens. The collimating unit is not necessarily needed in the present solution.

Microdisplay

A microdisplay can comprise an LCD (liquid chrystal device), DMD (digital micromirror device), or LCOS (liquid chrystal on silicon) based spatial modulator. When a conventional LCD is used, only on of the polarization directions is preserved. In addition, 20% - 40% of the light is lost due to the gaps between the effective pixels. A better solution is to use a micro-lens array (MLA) with the LCD, i.e. MLA-LCD, which case the light is guided through the effective pixels by the micro-lens array. LCD or MLA-LCD must be used in the configurations in which the light goes through the microdisplay. On the other hand, with the configurations where the light is reflected from the microdisplay all microdisplay possibilities can be used because there are also reflective versions of LCD's or MLA-LCD's, which have a mirrored back surface. The micro display may produce live video images or static images with no movement.

Focusing unit

Focusing unit projects the focusable image from the microdisplay or from the microdisplays on the target. The focusing unit can comprise for example a single lens, a Fresnel lens, a single mirror, a diffractive optical element, a hybrid refractive-diffractive element, or a combination of the said components. Preferably the focusing unit comprises of a set of lenses. The lenses in the focusing unit may have an antireflection coating to reduce reflection losses.

Monochromatic projector architectures

Figure 4A shows an embodiment of the data projector, which uses only one wavelength band. The data projector comprises the abovementioned source unit 402 with a single color, an optional collimating unit 404, a microdisplay 406 and a focusing unit 408. The source unit 402 provids light which is collimated by the collimating unit 404 to the microdisplay. The image of the microdisplay 406 is projected onto the target through the focusing unit 408. Figure 4B shows the same embodiment without the collimating unit.

Figure 4C shows another embodiment of th data projector, which uses only one light source 402. The data projector comprises a source unit 402 with a visible band of light, an optional collimating unit 404 which collimates the beam of light, an optional mirror 412 which directs the beam to the DMD microdisplay, and the DMD microdisplay 410 which reflects the light through the focusing unit 408 to the target. The target (not shown in Figures) can be any surface on which the user wants the image to be projected, for example, a wall, a sheet of paper, a book, a screen or the like.

When LCD, MLA-LCD or LCOS-based microdisplays are used, the other polarization direction, i.e. 50% of the light is lost. This loss is avoided in an embodiment which is presented in Figure 5. The one color beam from an source unit 402 is optionally collimated by using an optical unit 404, which may also be called a collimating unit, and directed to the polarization beamsplitter 502. The beam containing two polarizations is splitted into two directions both consisting of only one linearly polarized light. The first beam is reflected to the microdisplay 406, after which its polarization state is changed by 90 degrees by a quarter-wave plate 504, and finally reflected by a mirror 506 through another polarization beamsplitter 508 through the focusing unit 408 to the target. The second beam is reflected from a mirror 510 to the quarter-wave plate 512. The quarter-wave plate turns the polarization of the second beam by 90 degrees so that the beam will pass the microdisplay 406, which would have blocked the beam otherwise. The beamsplitter 508 reflects the beam through the focusing unit 408 to the target. This way the both polarization states are utilized. The first beam passes through the microdisplay 408 but in a different area than the second beam, and the beams are combined by a polarization beam splitter 508. The microdisplay 406 may also be replaced by two separate microdisplays so that both the beams pass different microdisplays.

Another modification of the previous embodiment is presented in Figure 6, in which the configuration is the same apart from that the quarter-wave plates 504, 512 and the microdisplay 406 are replaced with two microdisplays 602, 604. The microdisplays have polarization directions so aligned that both beams pass through. This embodiment has the advantage that quarter-wave plates are not needed.

Color projector architectures

Typically three wavelength bands are used in projection, namely red, green and blue. If several wavelength bands are used, the different wavelength bands are modulated with different microdisplays, or with different areas of one microdisplay, or with the same microdisplay but with different time moments in series, because mircodisplays are inherently monochromatic.

If separate microdisplays are used, the beams have to be combined before projection on the target. That is because it is usually easier to combine the beams before projection than project each beam with separate focusing units on the target. However, if several wavelength bands are desirable, each modulated by a microdisplay of its own, the device can comprise three separate single-color projectors to avoid beam combining, for example, because of the assembly tolerances.

One embodiment of the projector having three wavelength bands is presented in Figure 7. The three source units 702 form red, green and blue beams. The beams are optionally collimated by using the collimating units 404 and directed through the microdisplays 406. After the microdisplays the three beams are combined in an X-cube 704. The combined beam is projected by a focusing unit 408 on the target.

Another embodiment of the projector having three wavelength bands is presented in Figure 8. The three source units 702 form red, green and blue beams. The beams are optionally collimated by the collimating units 802 and directed through the microdisplays 804, after which the beams are combined. The two outermost beams are reflected from the mirrors 806, 808 to the X-cube 810 in which all three beams are combined together. The combined beam is projected by a focusing unit 408 on the target. The advantage of this embodiment is that the assembly will be easier because several components can easily be combined as a single component, for example: The collimating units 802 can form a single unit, for example a single Fresnel lens with separate areas for each beam. The microdisplays 804 can form a single unit, for example a single LCD or MLA-LCD with separate areas for each beam. The mirrors 806, 808 and the X-cube 810 can be joined together to form a single unit which case the mirrors can be either metallized surfaces or rely on the total internal reflection.

Further embodiments of the projector having three wavelength bands are presented in Figure 9, Figure 10 and Figure 11. The beams are re-

flected from the mirrors 902 to the focusing unit 408. The combination of the beams is implemented by using chromatic mirrors 1002. Optionally the mirrors can form a single unit.

One embodiment of the projector utilizing three wavelength bands is presented in Figure 12. The three source units 702 form red, green and blue beams which are directed through a lenticular lens 1202 to a microdisplay 406 and finally through the focusing unit 408 to the target. The lenticular lens illuminates every third row of the microdisplay with the same color. So in the other dimension, the spatial resolution on the target will be one third of the respective spatial resolution of the microdisplay. Figure 13 shows the same embodiment with the collimating units 404, which may simpify the optical design of the lenticular lens.

When using several wavelength bands, it is also possible to use one microdisplay by illuminating it in rapid series one wavelength band at a time. This solution simplifies the device configuration substantially. Because a convenient screen would need a refreshing frequency of at least 60 Hz, all bands should be shown during 17 ms time period. When three colors is used, this means an illumination time of 5,7 ms per color. So, the microdisplay should have a fast enough response time. DMD-based microdisplays have a response time of several kHz, so that is not a problem. The commercial LCD response time is typically 16 ms, but faster ones have already been developed. In a few years the response time of LCD is supposed to go down to 7 ms range which would be enough. It is known that when LEDs are driven in a rapidly pulsed mode, the total averaged optical output power can be the same as that used when they are driven in constant mode with the same averaged electrical power. Thus pulsing the LEDs affects negatively neither the power efficiency of the system nor the absolute optical power of the system.

One embodiment of the projector using three wavelength bands serially is shown in Figure 14. The three source units 702 form red, green and blue beams which are optionally collimated by the collimation unit 802. The three beams illuminate the transmissive microdisplay 406, from which the image is projected on the target by using a focusing unit 408. The source units are driven rapidly in series so that only one wavelength band is on at a time. This embodiment is particularly ben ficial because the d sign of the source units is such that each beam illuminat s the microarray and no additional

beam combiner is needed. In addition, the source units may comprise a single unit. So the structure is simple, compact and small.

Other embodiments of the projector using three wavelength bands serially are shown in Figure 15 and Figure 16. The three source units 702 form red, green and blue beams which are optionally collimated by the collimation units 404. In the embodiment of Figure 15, the beams are combined by using an X-cube 1502, whereas in the embodiment of Figure 16, the combination is made by using chromatic mirrors 1602. In both embodiments, the combined beams are directed to the reflective microdisplay 1506 by using an optional mirror 1504 and finally through the focusing unit 408 to the target. The reflective microdisplay is preferably a DMD. The source units are driven rapidly in series so that only one wavelength band is on at a time.

Also these color projector embodiments which use an LCD, MLA-LCD or LCOS-based microdisplay have the problem of 50% light loss because the display component acts as a polarizer. This loss can be avoided in a similar manner that was proposed with single-color projectors and illustrated in Figures 5 and 6. The same solution can be straightforwardly adapted most of the abovementioned color projector embodiments.

For example, Figure 17 presents the embodiment of Figure 14 combined with the idea of the embodiment of Figure 6. The three source units 702 form red, green and blue beams which are optionally collimated by the collimation unit 404. The beam is splitted into two beams with different polarizations in the polarization beamsplitter 502. Both beams are sent through separate microdisplays 602, 604 and combined again in a beamsplitter 508 and sent to the focusing unit 408. The source units are driven rapidly in series so that only one wavelength band is on at a time.

Another example is shown in Figure 18 where the embodiment of Figure 8 is combined with the embodiment of Figure 5. The system has three single color projector embodiments of Figure 5 in a stack so that the corresponding elements are in contact. Figure 18 presents one of these single color projectors inside the large box. The other projectors have not been included in the image and they are shown only schematically as small boxes. The single color projectors 1800 are combined by using two mirrors and an X-cube 1802 as in Figure 8. The combined beam is then projected on the target by using a focusing unit 408. This solution is particularly good for that many of its components are integrable to each other. For example, the collimation units can

comprise a single unit, the beamsplitters and mirrors between the source units and microdisplays can comprise a single unit, the microdisplays can comprise a single unit, the mirrors and the beamsplitters and the X-cube between the microdisplays and focusing unit can comprise a single unit.

Although in some of the abovementioned embodiments the three mentioned colors were red, green and blue, we are not restricted to these color combinations, but the colors can be any three colors in the visible range.

Electrical circuits can be implemented by hardware on a circuit board which comprises separate electronic components, by VLSI components (Very Large Scale Integrated Circuit), by FPGA components (Field-Programmable Gate Arrays) or preferably e.g. by ASIC circuit technology (Application Specific Integrated Circuit). Automatic data processing can be carried out in a PC computer or preferably by software run in a processor.

The projection method and data projector according to the invention are particularly suitable for the following uses:

- As a television replacement
- As a computer monitor replacement
- As a video projector
- As a slide presenter / dia projector

The solution of the invention can also be used as an accessory to or integrated into:

- Mobile phone
- DVD- and other media players
- Video camcorder
- Digital camera
- Personal Digital Assistant
- Laptop PC
- Handheld and desktop gaming devices
- Video conferencing device
- Multimedia devices at home, hotels, restaurants, cars, airplanes, ships and other vehicles, offices; public buildings such as hospitals, libraries, etc; and other locations
- Any other device in which low power consumption, small size and low price are important aspects.

All in all, the present solution leads to a significantly smaller projector configuration, using less power, yielding lower costs and providing higher durability than the existing devices.

Even though the invention is described above with reference to examples according to the accompanying drawings, it is clear that the invention is not restricted thereto but it can be modified in several ways within the scope of the appended claims.

Claims

1. A data projector, the data projector comprising:

a micro display having an image to be projected,

at least one light source transmitting in a narrow band of the visible radiation,

a beam forming component for each light source, each beam forming component comprising at least one diffractive element, and each beam forming element being designed to provide a desired projection shape and a uniform illumination onto the micro display,

and a focusing optical unit for projecting the image of the micro display on a target.

2. The data projector of claim 1, wherein the data projector comprises at least one green LED, at least one blue LED and at least one red LED as light sources.

3. The data projector of claim 1, wherein the data projector comprises an LC, DMD, MLA display or the like as the micro display.

4. The data projector of claim 1, wherein the data projector further comprises an optical unit between the beam forming component and the micro display for directing the optical radiation from the source to the micro display more efficiently, the optical unit being a lens, a mirror, a fresnel lens, a diffractive element, a micro lens array, a series of these or any combination thereof.

5. The data projector of claim 1, wherein the data projector further comprises:

means for dividing the beam of light from each light source into two beams with different polarizations, the micro display being divided into separate parts to which each beam of the two beams of each light source is directed, and

means for combining the two beams of light of each light source after the micro display.

6. The data projector of claim 1, wherein each beam forming component is designed for a visible band of the corresponding light source.

7. The data projector of claim 1, wherein each beam forming component is integrated with a corresponding light source.

8. The data projector of claim 1, wherein th image is a video image.

9. The data projector of claim 1, wherein the data projector is a part of a portable electronic device.

L3

(57) Abstract

The present solution relates to a data projector, which comprises: a micro display having an image to be projected, at least one light source transmitting in a narrow band of the visible radiation, a beam forming component for each light source, each beam forming component comprising at least one diffractive element, and each beam forming element being designed to provide a desired projection shape and a uniform illumination onto the micro display, and a focusing unit for projecting the image of the micro display on a target surface.

(Figure 4)

L4

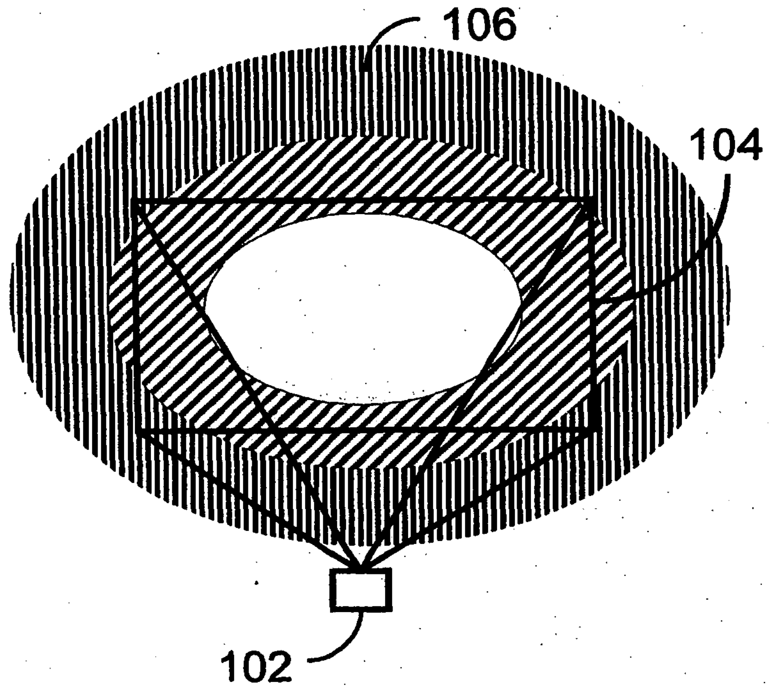


FIG. 1

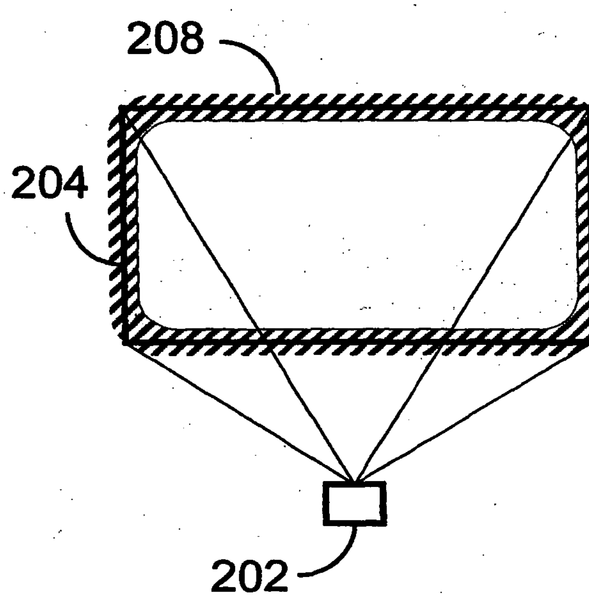


FIG. 2

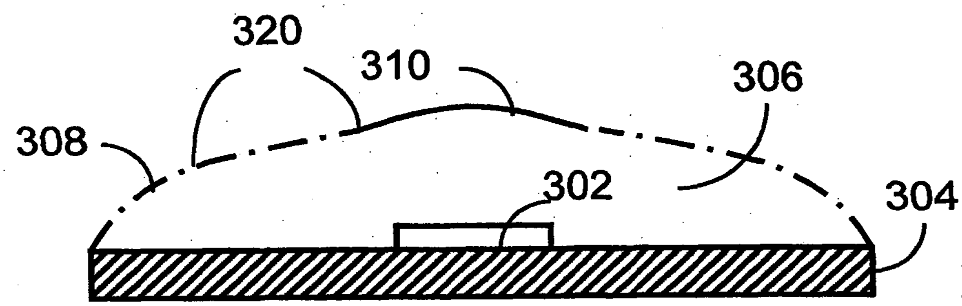


FIG. 3A

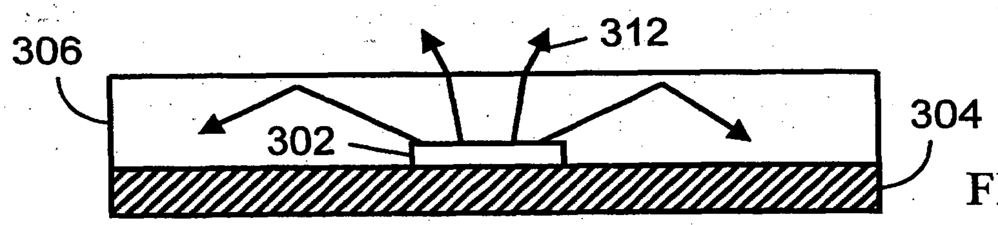


FIG. 3B

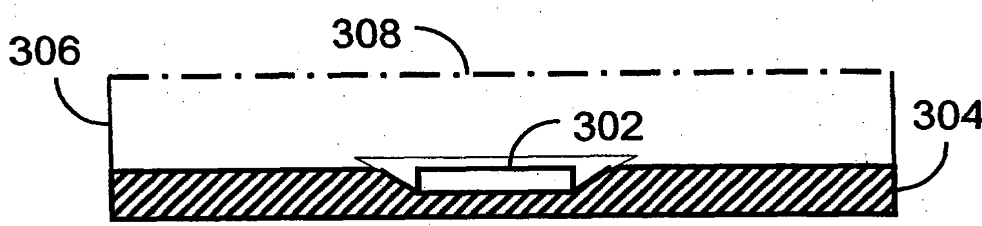


FIG. 3C

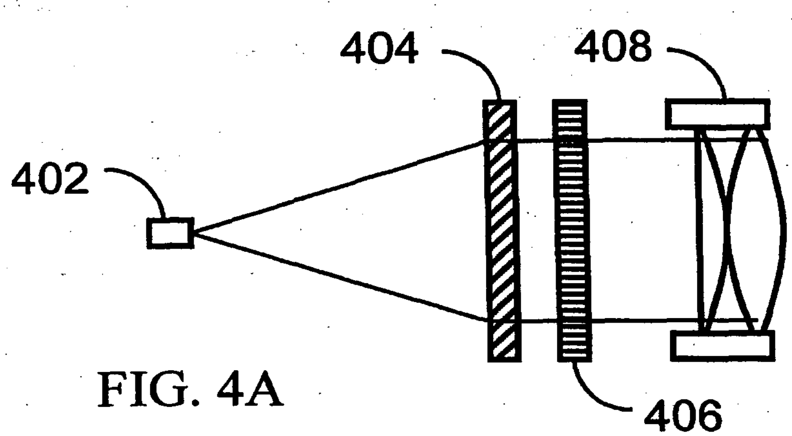


FIG. 4A

L4

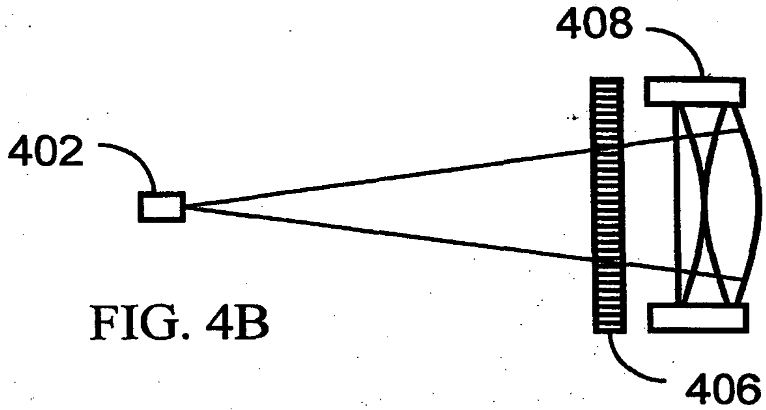


FIG. 4B

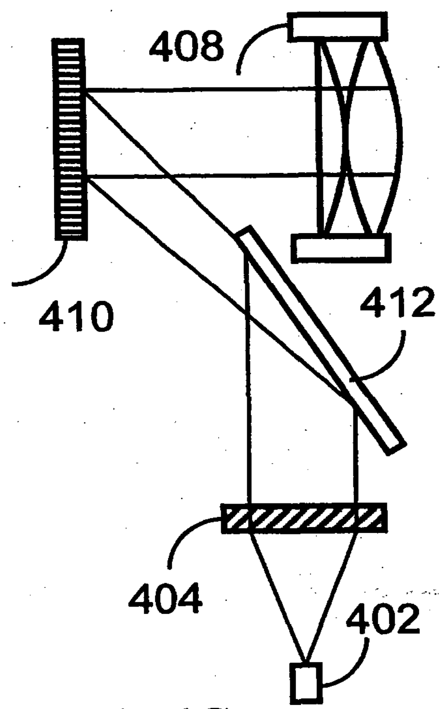
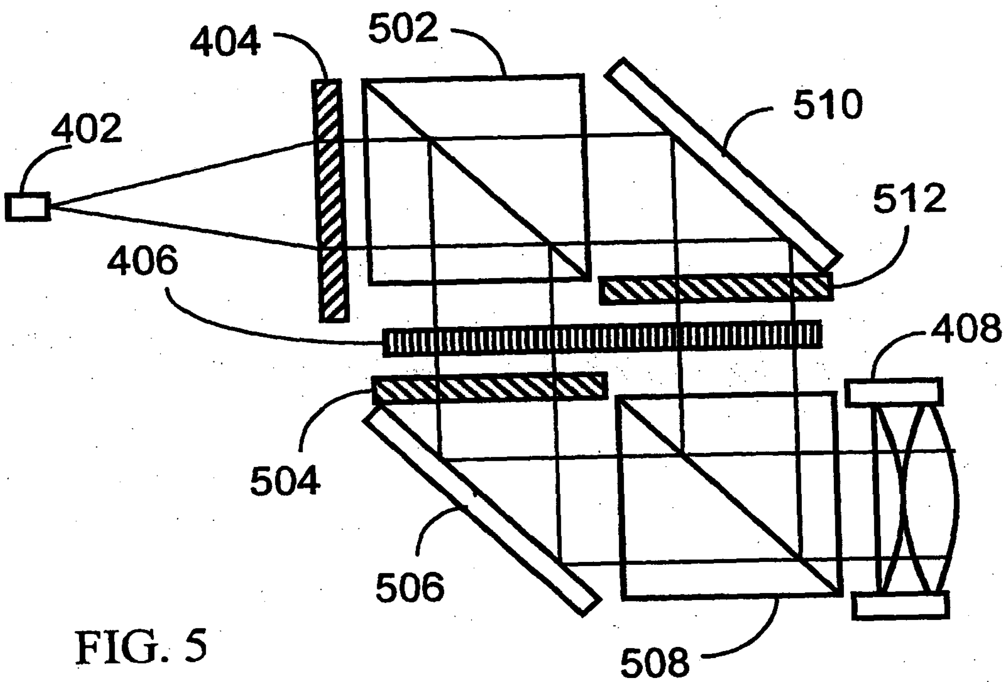


FIG. 4C

L4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402
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512
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408
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508

FIG. 5

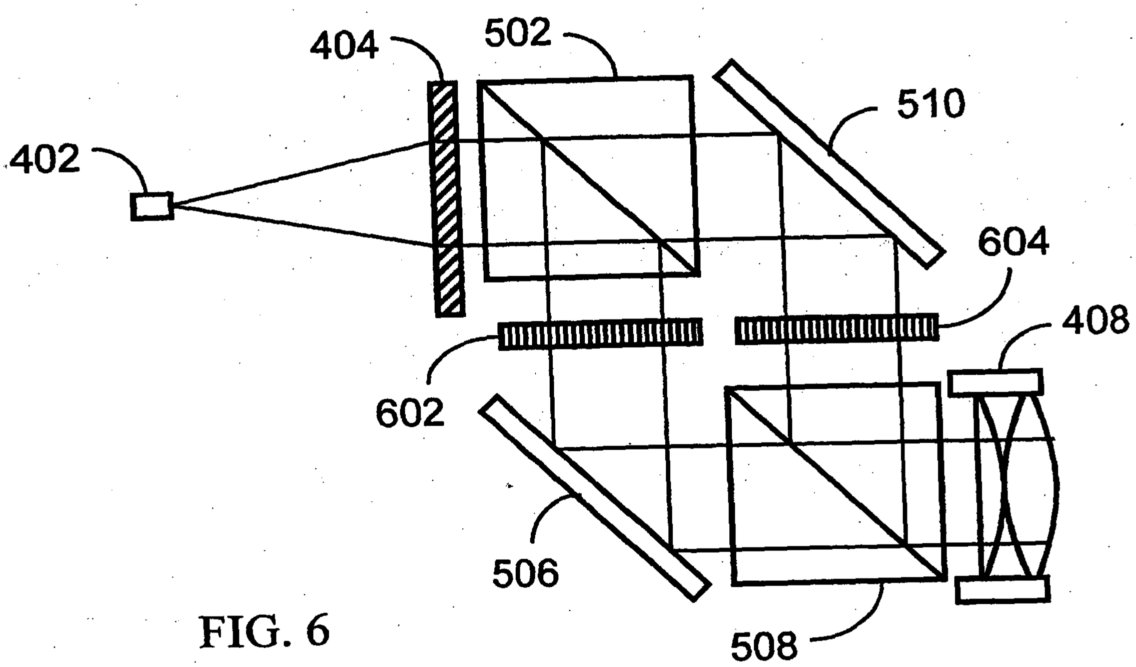
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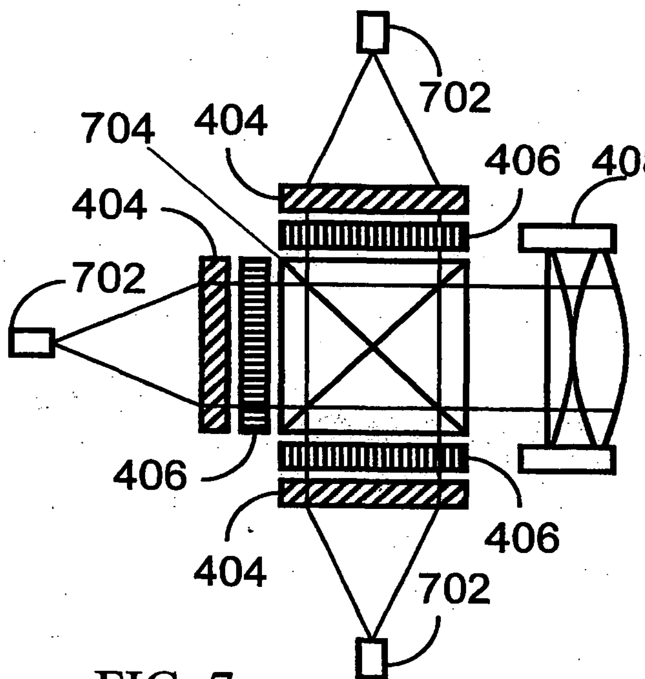
FIG. 6

L4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704
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408
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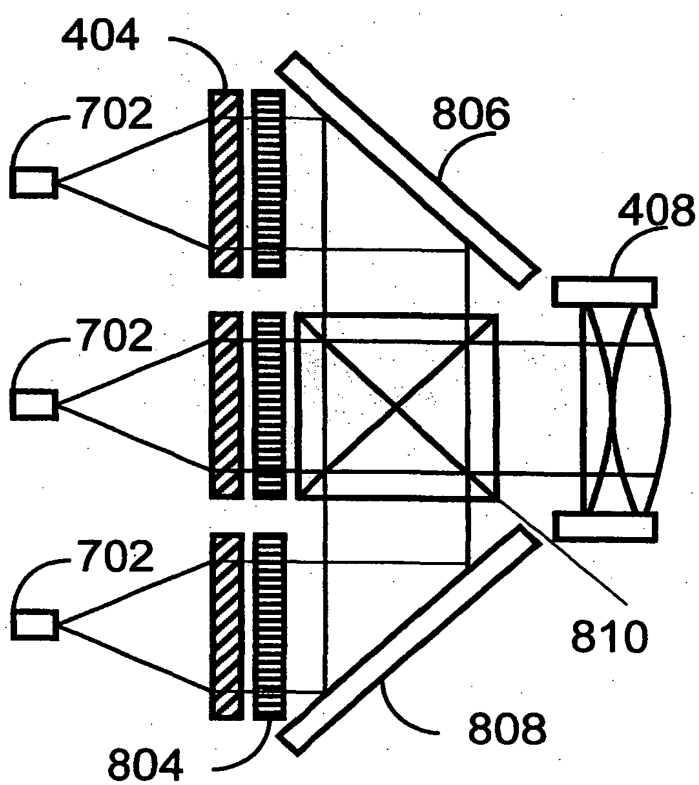
702
406
406
404
702

FIG. 7


404
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804

FIG. 8

L4

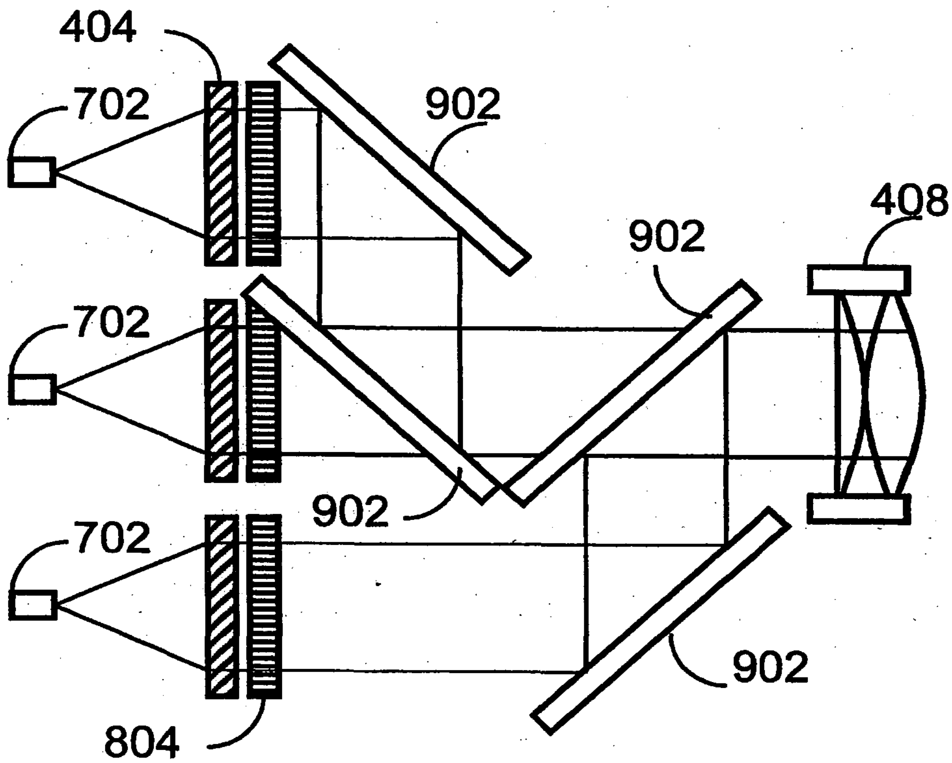

FIG. 9

L4

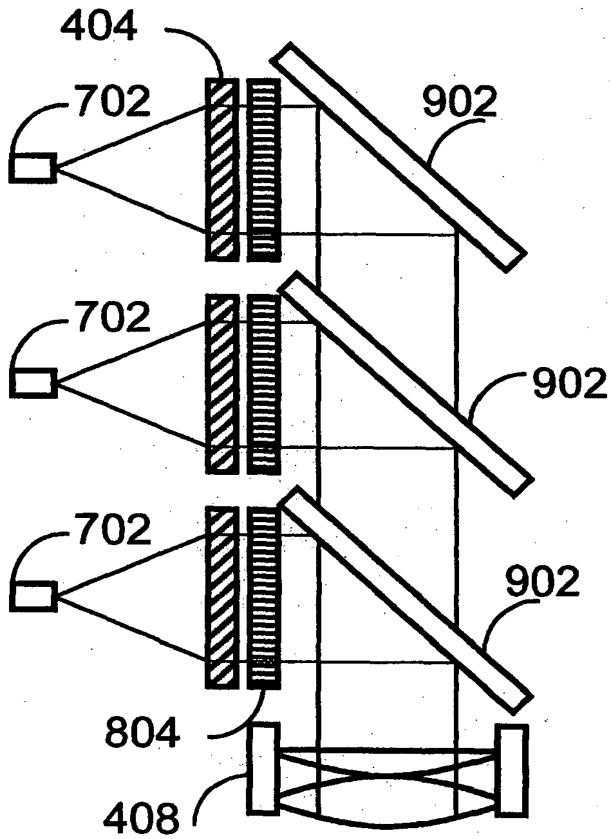

FIG. 10

L4

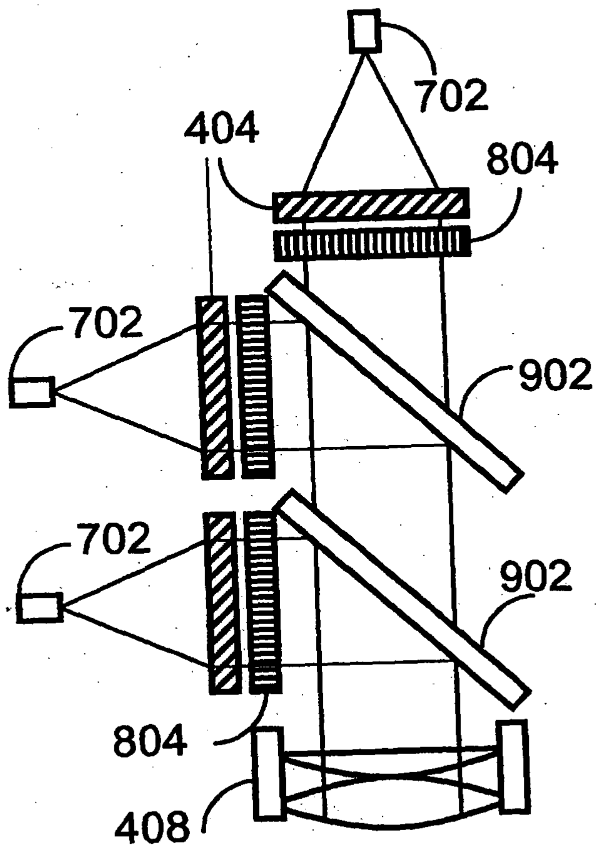

FIG. 11

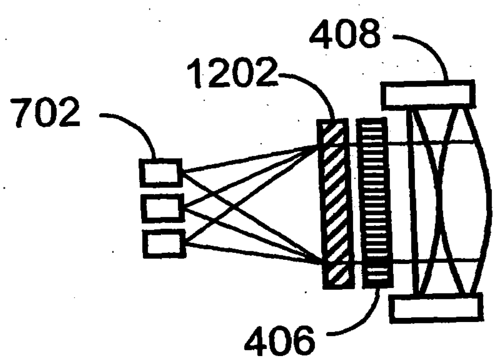

FIG. 12

L4

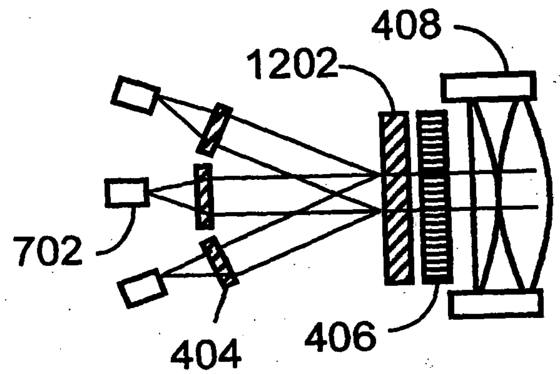

FIG. 13

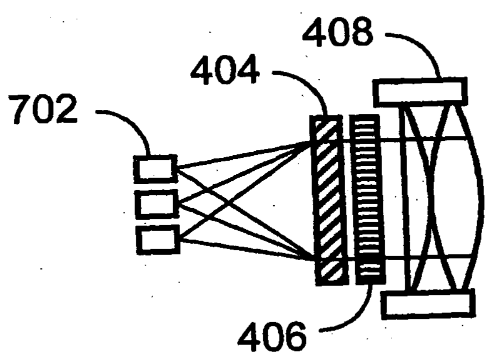

FIG. 14

L 4

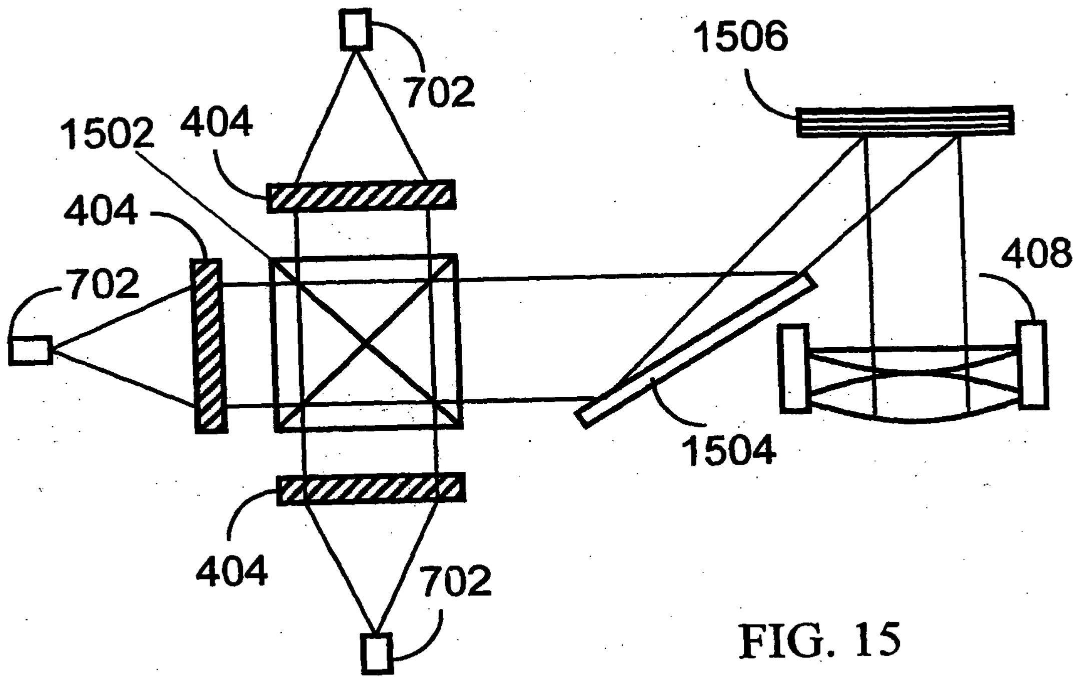

FIG. 15

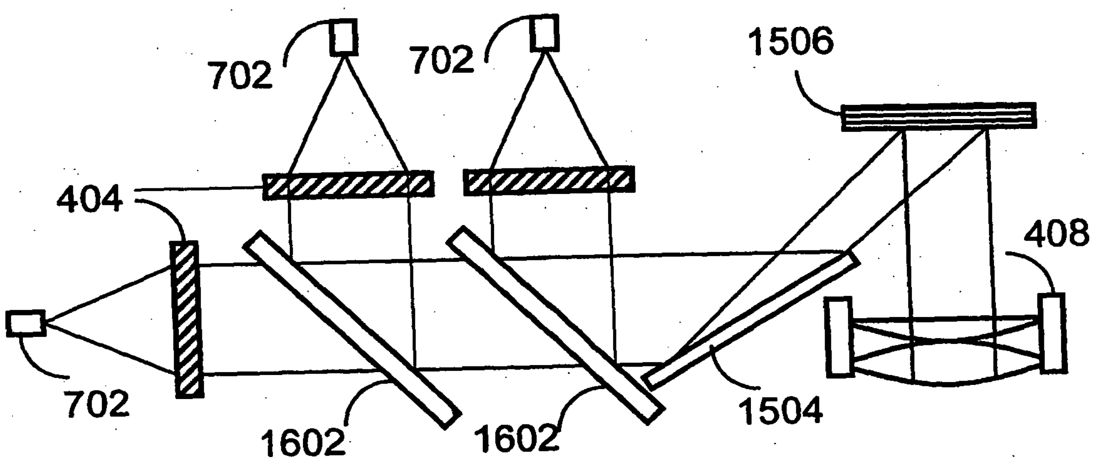

FIG. 16

L4

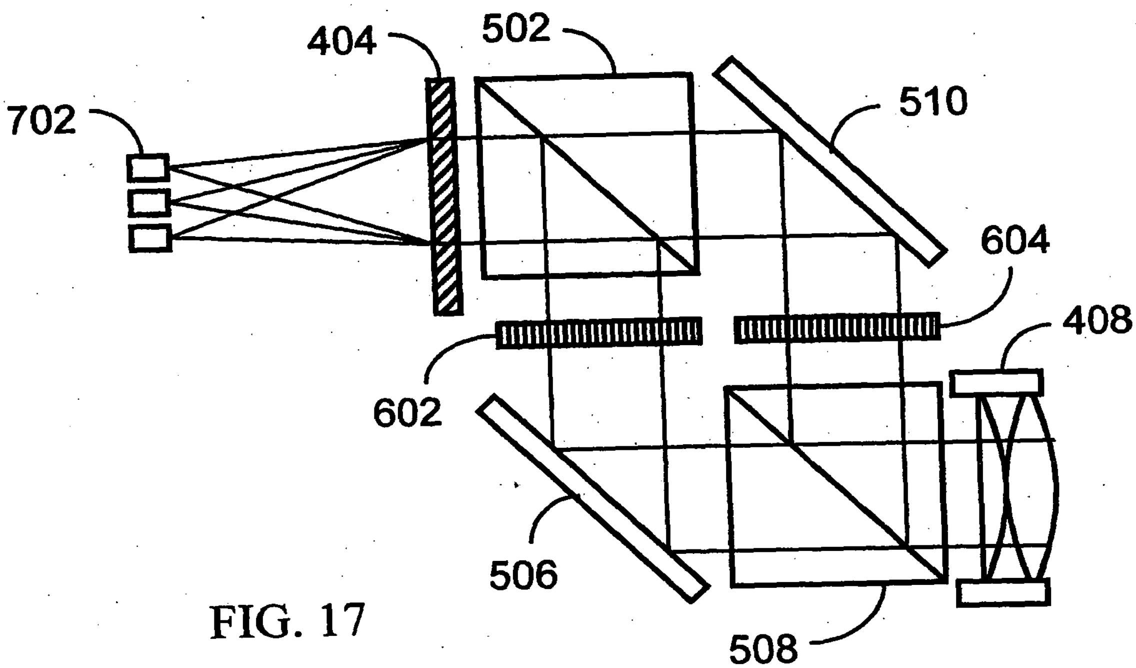

FIG. 17

L4

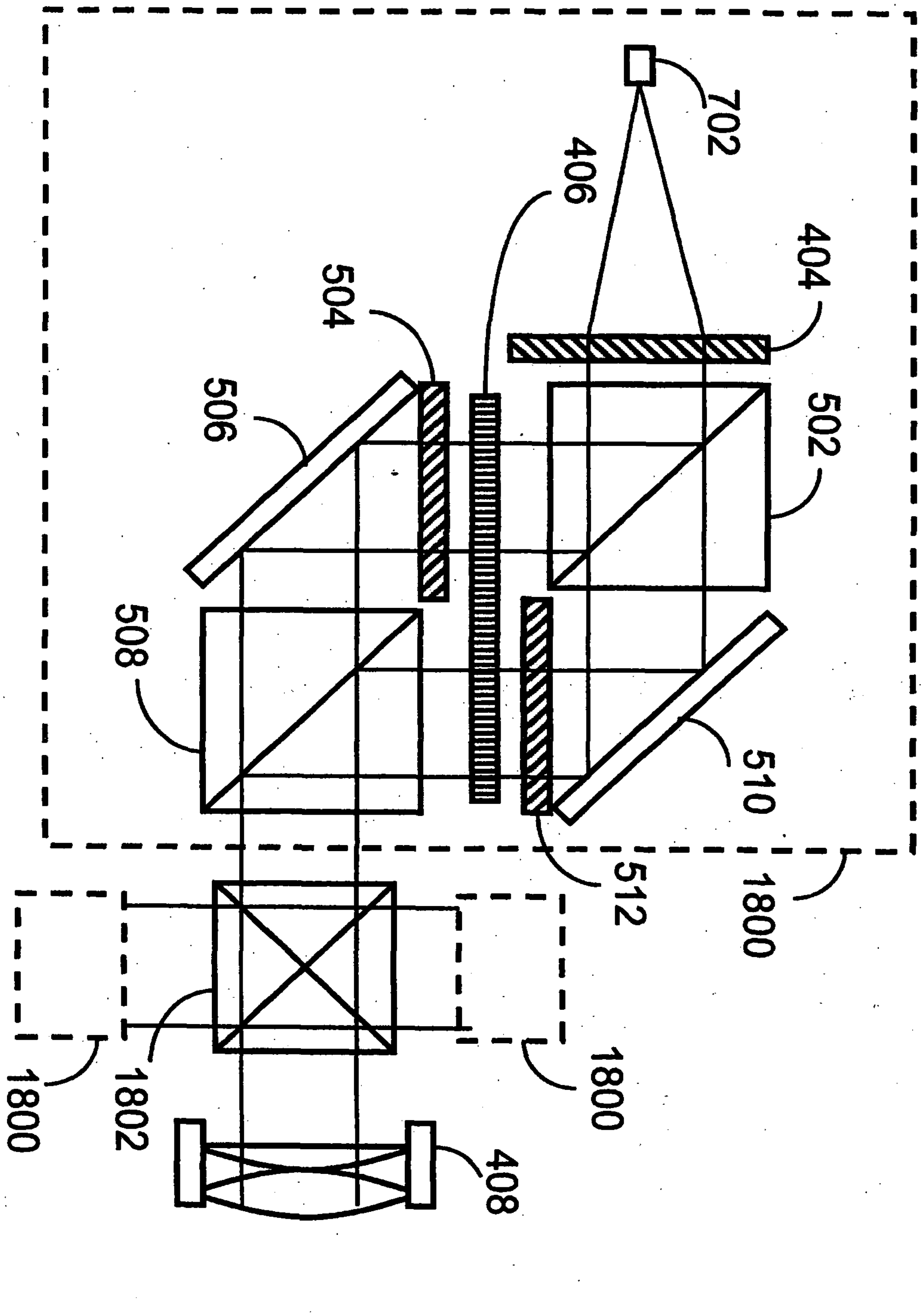

FIG. 18